[0071] **FIGS. 11, 12**, and **13** show the examples of combination of graphical user interface and tactile feedback communication;

[0072] **FIG. 14** shows a data flow when the user received feedback before interacting with the graphical user interface; and

[0073] **FIGS. 15A and 15B** show example of the multi-layered piezoelectric bending actuator.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0074] **FIG. 1** schematically shows a hardware configuration of a mobile apparatus **100** embodying this invention. As shown in this figure, the mobile apparatus **100** includes a data processing unit **101**, a signal producing unit **102**, a user input device **103**, a user output device **104**, and a haptic display **105**.

[0075] The data processing unit **101**, acting as a main controller, executes a variety of application programs under the environment provided by the operating system (OS). In general, application programs run through user interaction. In this embodiment, some of the application programs use tactile feedback function as described below. The data processing unit **101** can be constructed by microprocessor with RAM (Random Access Memory) and ROM (Read Only Memory).

[0076] The user input device **103** may be a keyboard or keypad, and the user output device **104** may be a flat panel type display like LCD (liquid crystal display). Both the user input device **103** and the user output device **104** may be also integrated into a single device such as touch panel display.

[0077] In response to the user input data/command through the user input device **103**, the data processing unit **101** operates and the provides the resultant data to the user output device **103** and signal producing unit **102** respectively.

[0078] The signal producing unit **102** generates or modulates, in accordance with the resultant data provided by the data processing unit **101**, the signal that is a voltage function of time, with amplitude, shape and period defined by the interface designer. The example of the generated signal is square wave, sinusoidal and so on. The signal producing unit outputs the signal into the haptic display **105**.

[0079] The haptic display **105** converts the signal from the signal producing unit **102** into the force or tactile pattern. The patterns are communicated to the user who holds the mobile apparatus **100** on his/her palm.

[0080] The mobile apparatus **100** may also install the other electric circuits and peripheral devices such as hard disk and network interface. However, these components are not depicted in the figure, since they are well known in the art and yet they do not pertain to the gist of this invention.

[0081] The haptic display **105** comprises at least one haptic device that can give tactile feedback on behalf of visible feedback. Each of the haptic devices converts the signal from the signal producing unit **102** into the force or tactile pattern.

[0082] Basically there are two ways to provide feedback using the haptic device.

[0083] 1) By placing it anywhere inside of the device. This construction would require mass

[0084] 2) By actuating a part of the display without using mass.

[0085] As described later, the haptic device does not require mass, so that it can be provided on almost any portion or part within the body of the mobile apparatus. For example, the haptic device can be embedded under the touch panel display that constitutes both the user input device **103** and the user output device **104**. By providing the haptic devices under the respective button area displayed on the touch panel display, it is possible to stimulate the specific button in response to the user-input-operation and directly give the user's finger the tactile feedback.

[0086] **FIG. 2** illustrates a physical configuration of the haptic device. This type of haptic device comprises a bending piezoelectric actuator that is rigidly supported on one end with the mass attached to the other end.

[0087] **FIG. 3** illustrates anther example of the structure of the haptic device. This type of haptic device comprises a bending piezoelectric actuator that is rigidly supported on both ends (bridge configuration) with the mass attached in the middle.

[0088] In this embodiment, the haptic device comprises single or multiple layer piezoelectric bending actuator. **FIG. 4** schematically shows the structure and the principle of the operation of single or multiple layer piezoelectric bending actuator. As shown in this figure, the multiple layer piezoelectric bending actuator comprises the upper layer piezoelectric actuator and the lower layer piezoelectric actuator. The piezoelectric actuator can either expand or contract in accordance with the direction of the applied voltage. By applying, to the upper layer, a certain voltage of the direction opposite to the lower layer, the upper layer contracts and the lower layer expands at the same time. Resultantly, the multiple layer piezoelectric bending actuator bends upward or downward as a whole.

[0089] The displacement value ΔY of the piezoelectric bending actuator and the force F generated by the piezoelectric bending actuator are directly proportional to voltage applied to the actuator. More specifically, they may be calculated, for example, by using the following formulas for the example shown in **FIG. 4**.

[0090] The displacement value ΔY of the multiple layer piezoelectric bending actuator can be calculated by using the following formula.

$$\Delta Y = k_1 \cdot d_{31} (L/t)^2 \cdot V$$

[0091] k_1: correction constant value

[0092] d_{31}: piezoelectric constant value

[0093] L: length of the actuator

[0094] t: thickness of one layer of the actuator

[0095] V: voltage applied to the actuator

[0096] It would be appreciated that the value ΔY is much larger than the longitudinal contraction and expansion of the each layer.